

Friction

Engineering Mechanics: Dynamics

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Friction

- ▶ models the interaction between objects in contact
- ▶ opposes the relative motion between objects

Experimental observations (Leonardo da Vinci, 1452–1519; Guillaume Amontons, 1663–1705; Charles-Augustin de Coulomb, 1736–1806)

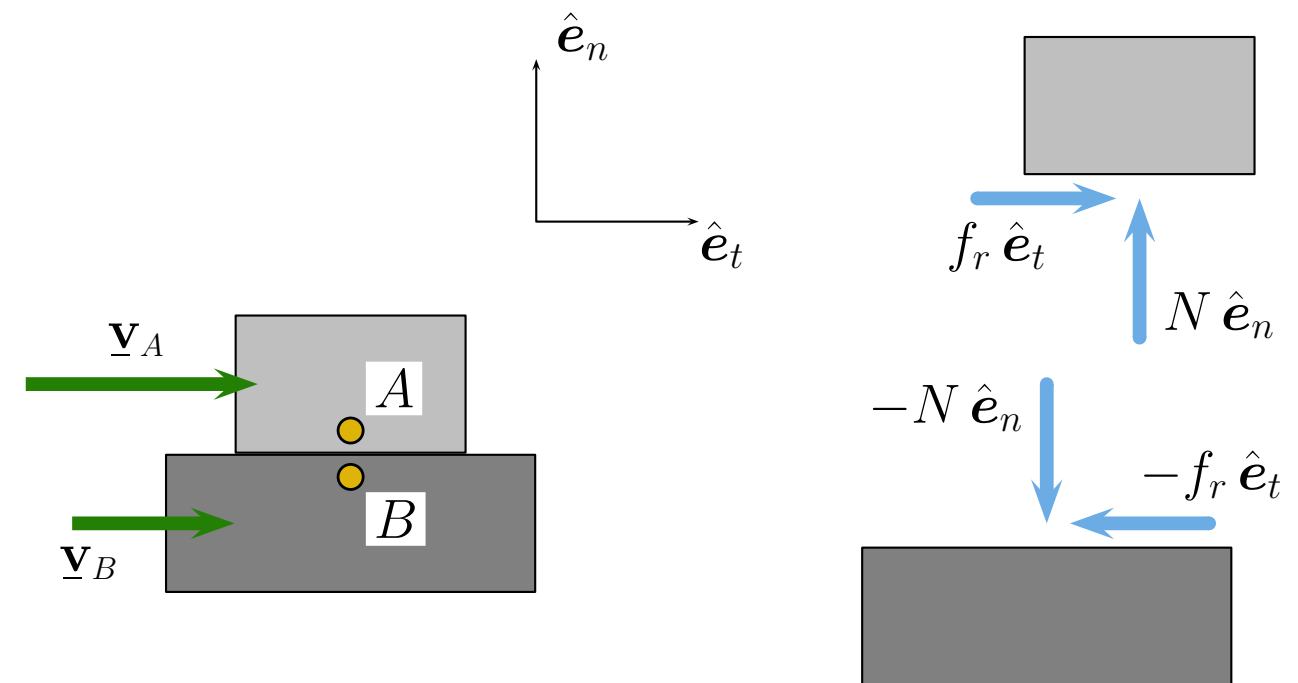
- ▶ independent of the contact area (*approximate*)
- ▶ when relative motion exists
 - ▶ independent of the sliding velocity (*approximate*)
 - ▶ proportional to the magnitude of the normal force between the objects (*approximate*)

(\hat{e}_t, \hat{e}_n) are directions defined tangential and normal to the contact plane

$\underline{v}_{\text{slip}} = \underline{v}_A - \underline{v}_B = v_{\text{slip}} \hat{e}_t$: slip velocity

$\underline{N} = N \hat{e}_n$: Normal force between objects

$\underline{f}_r = f_r \hat{e}_t$: friction force between objects



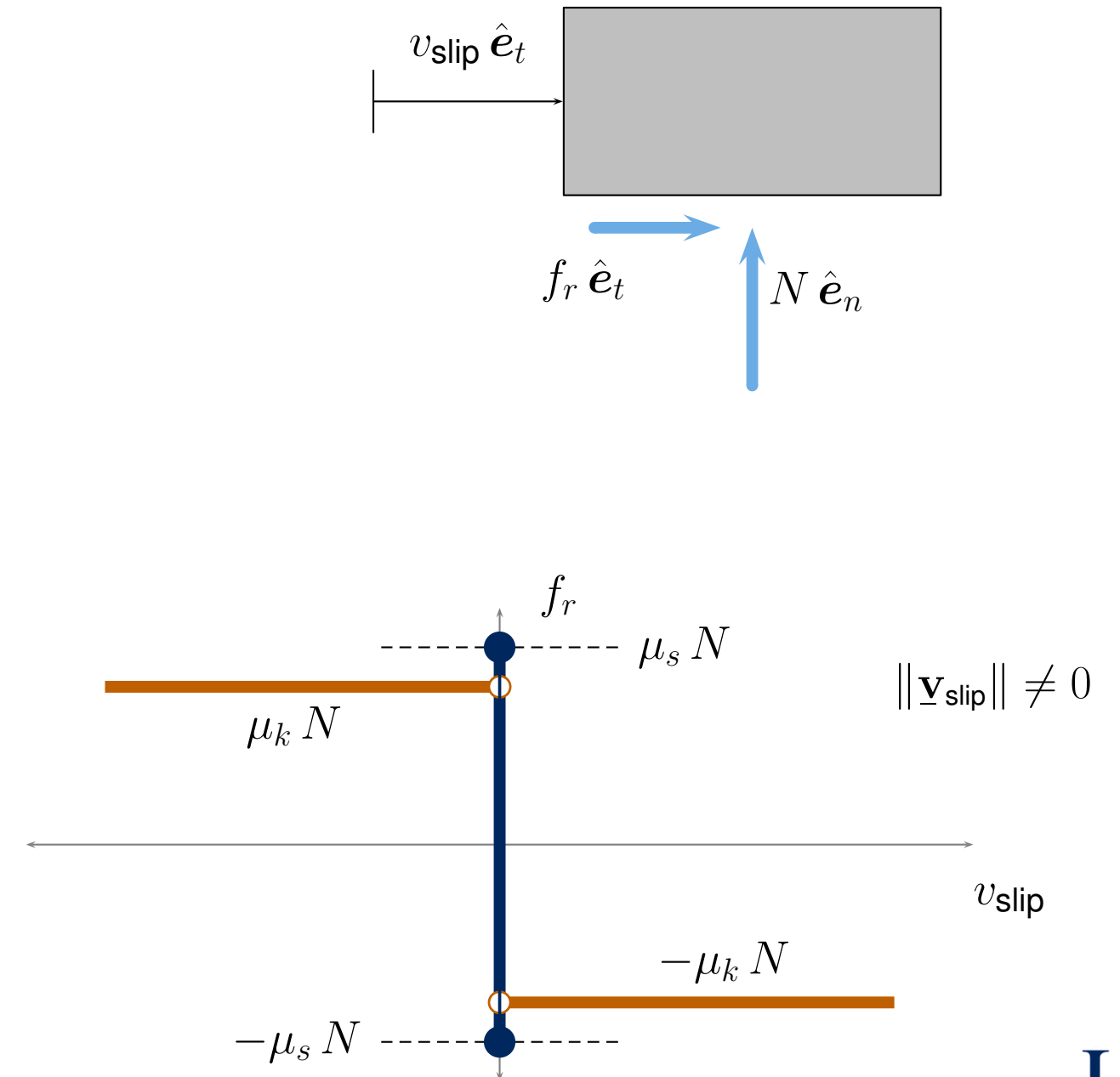
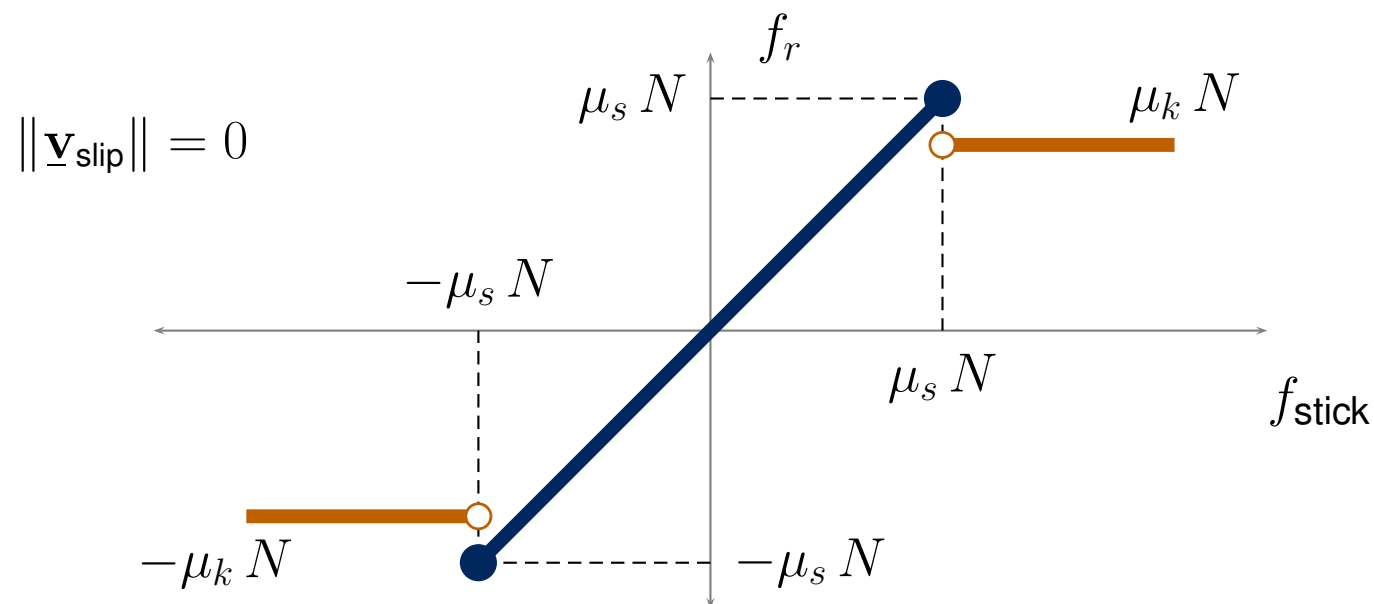
Coulomb friction (most common model for friction)

Identify $\underline{f}_{\text{stick}} = f_{\text{stick}} \hat{e}_t$ as the force required to maintain stick between the objects, then

$$f_r = \begin{cases} f_{\text{stick}}, & v_{\text{slip}} = 0, \quad \|f_{\text{stick}}\| \leq \mu_s N, \\ -\mu_k N \underbrace{\left(\frac{v_{\text{slip}}}{\|v_{\text{slip}}\|} \right)}_{\text{slip direction}}, & \|v_{\text{slip}}\| \neq 0. \end{cases}$$

μ_s : Static coefficient of friction

μ_k : Dynamic (kinetic) coefficient of friction



Transitions occur between slip and stick

